Outcome of conservative and surgical treatment for luxations of the equine superficial digital flexor tendon from the calcaneal tuber

Federici, M ; Fürst, Anton E ; Hoey, S ; Bischofberger, Andrea S

Abstract: The objective of this study was to report the outcome of horses treated either conservatively or surgically for luxation of the superficial digital flexor tendon (SDFT) from the calcaneal tuber. Medical records of horses with diagnosed SDFT luxations from the calcaneal tuber were reviewed (1993–2015) and long-term follow-up examinations and owner questionnaires performed. Survival to hospital discharge, complications, final SDFT position, soundness and return to intended use were compared between conservatively or surgically treated horses. Following conservative treatment all horses (n = 8) survived to hospital discharge. At long-term follow-up 71.4% (5/7) had returned to intended use. The SDFT was unstable in all of them resulting in a mild mechanical lameness. Nine horses underwent surgical treatment. The SDFT was reduced and maintained in position with a synthetic mesh and sutures (n = 2), with a synthetic mesh, sutures and suture screws (n = 6) or with sutures and suture screws (n = 1). Only 66.7% (6/9) of the horses survived to hospital discharge. Fatal complications including support limb laminitis (1/9), implant infection (1/9), and support limb laminitis plus infection (1/9) occurred. All horses available for long-term follow-up (n = 5) were clinically sound and 80% (4/5) had returned to intended use. Following conservative treatment, a mild mechanical lameness will persist but will not prevent the horses from returning to their intended use. Surgical repair can result in a stable fixation of the SDFT with long-term soundness and return to intended use; however, fatal complications (support limb laminitis, infection) can occur leading to the euthanasia of the horse in the immediate post-operative period.

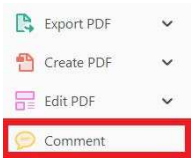
DOI: https://doi.org/10.1111/eve.12809

WILEY

USING e-ANNOTATION TOOLS FOR ELECTRONIC PROOF CORRECTION

Required software to e-Annotate PDFs: Adobe Acrobat Professional or Adobe Reader (version 11 or above). (Note that this document uses screenshots from Adobe Reader DC.)
The latest version of Acrobat Reader can be downloaded for free at: http://get.adobe.com/reader/

Once you have Acrobat Reader open on your computer, click on the Comment tab (right-hand panel or under the Tools menu).



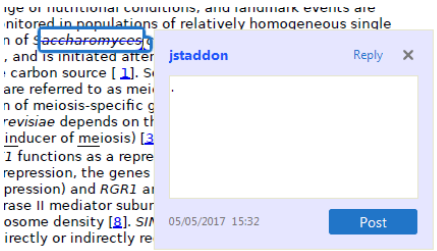
This will open up a ribbon panel at the top of the document. Using a tool will place a comment in the right-hand panel. The tools you will use for annotating your proof are shown below:

1. Replace (Ins) Tool – for replacing text.

Strikes a line through text and opens up a text box where replacement text can be entered.

How to use it:

- Highlight a word or sentence.
- Click on .
- Type the replacement text into the blue box that appears.

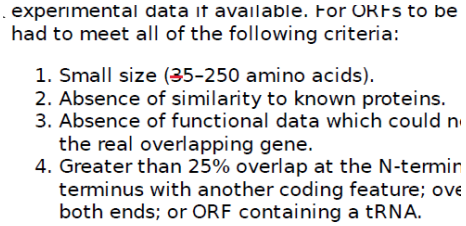


2. Strikethrough (Del) Tool – for deleting text.

Strikes a red line through text that is to be deleted.

How to use it:

- Highlight a word or sentence.
- Click on .
- The text will be struck out in red.

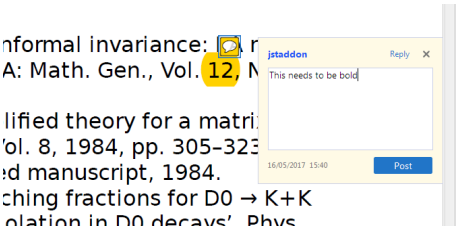


3. Commenting Tool – for highlighting a section to be changed to bold or italic or for general comments.

Use these 2 tools to highlight the text where a comment is then made.

How to use it:

- Click on .
- Click and drag over the text you need to highlight for the comment you will add.
- Click on .
- Click close to the text you just highlighted.
- Type any instructions regarding the text to be altered into the box that appears.

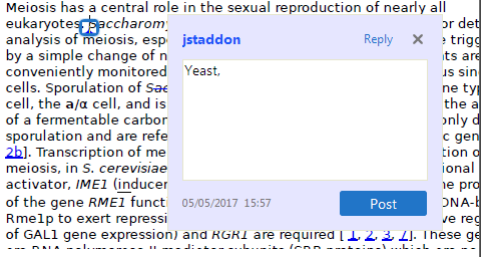


4. Insert Tool – for inserting missing text at specific points in the text.

Marks an insertion point in the text and opens up a text box where comments can be entered.

How to use it:

- Click on .
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the box that appears.



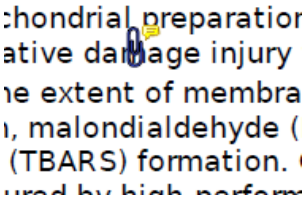
5. Attach File Tool – for inserting large amounts of text or replacement figures.

Inserts an icon linking to the attached file in the appropriate place in the text.

How to use it:

- Click on .
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.

The attachment appears in the right-hand panel.

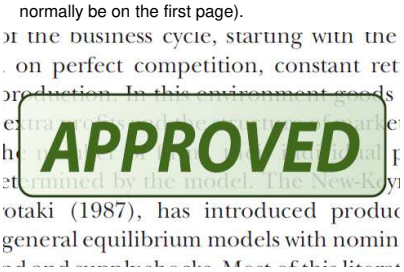


6. Add stamp Tool – for approving a proof if no corrections are required.

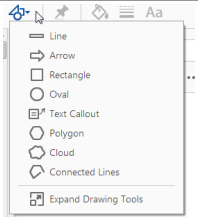
Inserts a selected stamp onto an appropriate place in the proof.

How to use it:

- Click on .
- Select the stamp you want to use. (The Approved stamp is usually available directly in the menu that appears. Others are shown under *Dynamic*, *Sign Here*, *Standard Business*).
- Fill in any details and then click on the proof where you'd like the stamp to appear. (Where a proof is to be approved as it is, this would normally be on the first page).

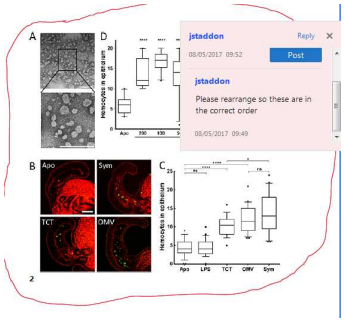


Drawing tools available on comment ribbon



7. Drawing Markups Tools – for drawing shapes, lines, and freeform annotations on proofs and commenting on these marks.

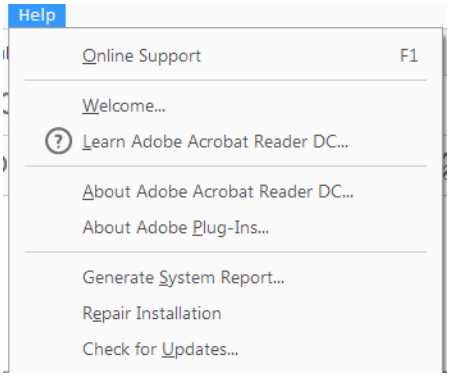
Allows shapes, lines, and freeform annotations to be drawn on proofs and for comments to be made on these marks.



How to use it:

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, right-click on shape and select *Open Pop-up Note*.
- Type any text in the red box that appears.

For further information on how to annotate proofs, click on the Help menu to reveal a list of further options:



Author Query Form

Journal: EVE
Article: 12809

Dear Author,
During the copy-editing of your paper, the following queries arose. Please respond to these by marking up your proofs with the necessary changes/additions. Please write your answers on the query sheet if there is insufficient space on the page proofs. Please write clearly and follow the conventions shown on the attached corrections sheet. If returning the proof by fax do not write too close to the paper's edge. Please remember that illegible mark-ups may delay publication.
Many thanks for your assistance.

Query reference	Query	Remarks
1	**AUTHOR: Please confirm that given names (red) and surnames/family names (green) have been identified correctly.**	
2	**AUTHOR: Please give details of any institutional, private or commercial funding for this work.**	
3	**AUTHOR: Figure 1 has been saved at a low resolution of 90 dpi. Please resupply at 600 dpi. Check required artwork specifications at https://authorservices.wiley.com/asset/photos/electronic_artwork_guidelines.pdf**	
4	**AUTHOR: Figure 2 has been saved at a low resolution of 150 dpi. Please resupply at 300 dpi. Check required artwork specifications at https://authorservices.wiley.com/asset/photos/electronic_artwork_guidelines.pdf**	

Equine vet. Educ. (2017) •• (••) ••-••
doi: 10.1111/eve.12809

Original Article

Outcome of conservative and surgical treatment for luxations of the equine superficial digital flexor tendon from the calcaneal tuber

M. Federici[†], A. E. Fürst[†], S. Hoey[‡] and A. S. Bischofberger[†,*]

[†]Equine Hospital, Vetsuisse Faculty, University of Zürich, Zürich, Switzerland and [‡]Section of Diagnostic Imaging, Veterinary Hospital, University College Dublin, Belfield, Dublin, Ireland.
**Corresponding author email: abischofbergert@vetclinics.uzh.ch*

Keywords: horse; calcaneal tuber; superficial digital flexor tendon; luxation; suture screw

Summary

The objective of this study was to report the outcome of horses treated either conservatively or surgically for luxation of the superficial digital flexor tendon (SDFT) from the calcaneal tuber. Medical records of horses with diagnosed SDFT luxations from the calcaneal tuber were reviewed (1993–2015) and long-term follow-up examinations and owner questionnaires performed. Survival to hospital discharge, complications, final SDFT position, soundness and return to intended use were compared between conservatively or surgically treated horses. Following conservative treatment all horses (n = 8) survived to hospital discharge. At long-term follow-up 71.4% (5/7) had returned to intended use. The SDFT was unstable in all of them resulting in a mild mechanical lameness. Nine horses underwent surgical treatment. The SDFT was reduced and maintained in position with a synthetic mesh and sutures (n = 2), with a synthetic mesh, sutures and suture screws (n = 6) or with sutures and suture screws (n = 1). Only 66.7% (6/9) of the horses survived to hospital discharge. Fatal complications including support limb laminitis (1/9), implant infection (1/9) and support limb laminitis and infection (1/9) occurred. All horses available for long-term follow-up (n = 5) were clinically sound and 80% (4/5) had returned to intended use. Following conservative treatment, a mild mechanical lameness will persist but will not prevent the horses from returning to their intended use. Surgical repair can result in a stable fixation of the SDFT with long-term soundness and return to intended use; however, fatal complications (support limb laminitis, infection) can occur leading to the euthanasia of the horse in the immediate post-operative period.

Introduction

Luxation of the superficial digital flexor tendon (SDFT) from the calcaneal tuber is an uncommon but well recognised condition in horses (Phillips 2000). The displacement of the fibrocartilaginous cap (FCC) of the SDFT during the stance phase and the possible manual dislocation of the FCC are pathognomonic for this condition (Meagher and Aldrete 1989) (Supplementary Item 1). Three distinct forms of luxations of the SDFT have been reported: a lateral displacement with rupture of the medial calcaneal retinaculum, a medial displacement with rupture of the lateral calcaneal retinaculum and splitting of the FCC of the SDFT (Auer 2012). The SDFT luxation can be stable or unstable. In stable SDFT luxations, the SDFT is displaced towards lateral or medial and its FCC is permanently positioned on the abaxial aspect of the calcaneal tuber. In unstable SDFT luxations the FCC can move back and forth from the point of the calcaneal tuber to its abaxial aspect during motion (Wright and Minshall 2012).

Conservative therapy consisting of stall rest, external coaptation with full-limb casts and/or bandages and controlled light exercise for 4–6 months has been described to treat this condition (Auer 2012). However, a persistent mechanical lameness has been found following conservative therapy, limiting the use of these horses for dressage but allowing them to be used for racing or show jumping (Dyson 2010). A peritendinous injection of a sclerosing agent was helpful in some horses to stabilise the luxated SDFT (Dyson 2010).

Some authors advocate that surgical repair is essential for affected horses to return to full athletic function (Auer 2012). Various surgical techniques aiming to restore the anatomical position of the SDFT over the plantar aspect of the calcaneal tuber have been reported. A good outcome was reported with medial luxation of the SDFT using only a 2-layer suture repair of the lateral retinaculum (Reiners *et al.* 2000). Repair of the torn retinaculum with sutures and a mesh has been described (Scott *et al.* 1982; Phillips 2000), whereby a successful outcome was achieved in 50% of the cases (Phillips 2000). In 2 mature horses with lateral luxations of the SDFT, the medial retinaculum was sutured and 2 cancellous bone screws were placed on the lateral aspect of the calcaneal tuber to prevent the SDFT from re-luxating (Meagher and Aldrete 1989).

Instead of "luxation" of the SDFT, Wright and Minshall (2012) used the term "subluxation" to describe this condition, because the FCC of the SDFT still remained in contact with the apex of the calcaneal tuber. They reported 7 horses with unstable SDFT subluxations. All the horses had evidence of longitudinal tearing of the FCC. The defect in the FCC created a buttonhole effect with the calcaneal tuber. Bursoscopic partial resection of the FCC and the associated torn retinaculum creating a stable subluxation of the SDFT abaxially to the calcaneal tuber lead to clinical improvement and return to work in 6 out of 7 horses (Wright and Minshall 2012).

The aims of this study were: 1) to report retrospectively the survival to hospital discharge, complications, long-term survival, cosmetic outcome, SDFT position and stability, soundness and return to intended use of horses treated conservatively and surgically for lateral or medial luxations of the SDFT from the calcaneal tuber; and 2) to describe a novel surgical technique, using suture screws, sutures and a

E V E Journal Code | 12809 Manuscript No. | WILEY | Dispatch: 10.8.17 No. of pages: 9 | CE: Keerthana J PE: Raghu B.

mesh to replace the torn calcaneal retinaculum and to reattach the SDFT to the plantar aspect of the calcaneal tuber.

The hypothesis was that surgical repair would result in a stable SDFT and soundness of the horse and that conservative treatment would result in an unstable SDFT leading to a mechanical lameness, preventing the horse from returning to its intended use.

Materials and methods

Horses admitted with uni- or bilateral luxations of the SDFT from the calcaneal tuber admitted to 2 equine referral hospitals between 1993 and 2015 were included in the study. The medical records were retrospectively reviewed and the following data recorded: case history; weight; previous use; duration from injury to admission; type of SDFT luxation (medial, lateral); AAEP lameness grade (AAEP Horse Show Committee 1999) at admission; treatment group (surgical, conservative); duration and type of external coaptation (bandage, cast); duration of administered antimicrobial and anti-inflammatory medication; duration of hospitalisation; and survival to hospital discharge. For conservatively treated horses the duration of stall rest was recorded. For the surgically treated horses additional details were included: the used implants (suture screws, sutures, mesh), recovery from general anaesthesia (hydropool, rope-assisted), duration the horse was kept in a sling and post-operative complications.

Diagnostic imaging

Radiographic and ultrasonographic examinations of the horses performed at hospital admission, at hospital discharge and at the time point of the long-term follow up examination were retrospectively evaluated. The following radiographic findings were assessed: soft tissue abnormalities, osteoarthritic changes, pathological bone reactions at the calcaneal tuber and at the implant site and signs of implant failure. The following ultrasonographic findings were recorded: synovitis (intertendinous calcaneal bursa, subcutaneous calcaneal bursa, tarsal sheath, talocrural joint), location, degree of displacement and lesions of the SDFT, visibility of the calcaneal retinaculae and of the rupture site, subcutaneous abnormalities as well as lesions in other tendons.

Conservative treatment

Conservative treatment consisted of systemically administered anti-inflammatory medication, local cooling, stabilising full-limb bandages and stall rest.

Surgical treatment

The horses were anaesthetised using a previously described protocol (Picek *et al.* 2010) and placed into lateral recumbency. The affected limb was placed undermost in horses suffering from lateral SDFT luxations and uppermost in horses suffering from medial SDFT luxations. The limb was routinely prepared for surgery. A curvilinear 20 cm skin incision was made over the plantaromedial or -lateral aspect of the calcaneal tuber (**Fig** 1**a**). After sharp dissection of the subcutaneous tissue and the tarsal fascia, the edges of the torn SDFT retinaculum were identified and if necessary sharply debrided. Self-taping 4.0 mm cancellous suture screws[1] were placed horizontally into the calcaneal tuber at the level of the retinaculum insertion, in approximately 8 mm intervals. For each screw, a 2.5 mm drill hole was created under fluoroscopic guidance and the suture screws were manually inserted. Large diameter nonabsorbable sutures were then placed in a simple-interrupted pattern with bites going through the abaxial aspect of the FCC of the SDFT and through the eyelet of the suture screws. The sutures were successively tightened and tied under manual reposition of the FCC over the calcaneal tuber (**Fig** 1**b**). In 2 horses (Horses 9 and 10) the ends of the torn retinaculum were apposed using sutures in a simple interrupted pattern without using suture screws. Finally, a synthetic mesh was fixed over the repair with single interrupted sutures using nonabsorbable suture material going through the eyelet of the suture screws (n = 7) or through the periretinacular tissue (n = 2) abaxially and through the FCC of the SDFT axially (**Fig** 1**c**). The tarsal fascia and subcutaneous tissue were closed with absorbable suture material in a simple continuous pattern. The skin was apposed using nonabsorbable suture material in a simple interrupted pattern or using skin staples.

Recovery and postoperative period

Horses were either recovered from general anaesthesia assisted with head and tail ropes in a full-limb cast or they were recovered in a hydropool system wearing a hydrophobic wound dressing. The horses were stall rested in a full-limb cast (following head and tail rope recovery) or they were placed into a sling[2] in a full-limb bandage (following hydropool recovery) (Fürst *et al.* 2006). A hoof bandage with raised heels and frog support with silicone packing material (Siltoform)[3] was applied to the contralateral limb to prevent support limb laminitis (Baxter and Morrison 2008). Broad-spectrum antimicrobials and anti-inflammatory medication were administered as described below.

Long-term outcome

Long-term follow-up was obtained through orthopaedic examinations. When horses were not available for a follow-up examination, an owner telephone interview was performed. The following information was recorded: survival, SDFT position and stability, cosmetic outcome, soundness, and return to intended use.

Post-mortem *examination*

Following owner consent, a post-mortem examination was performed in 4 of the surgically treated horses within 48 h of euthanasia. Two of these horses were subjected to euthanasia for reasons unrelated to the surgery. The affected limb was dissected and the surgical repair was macroscopically and histologically described.

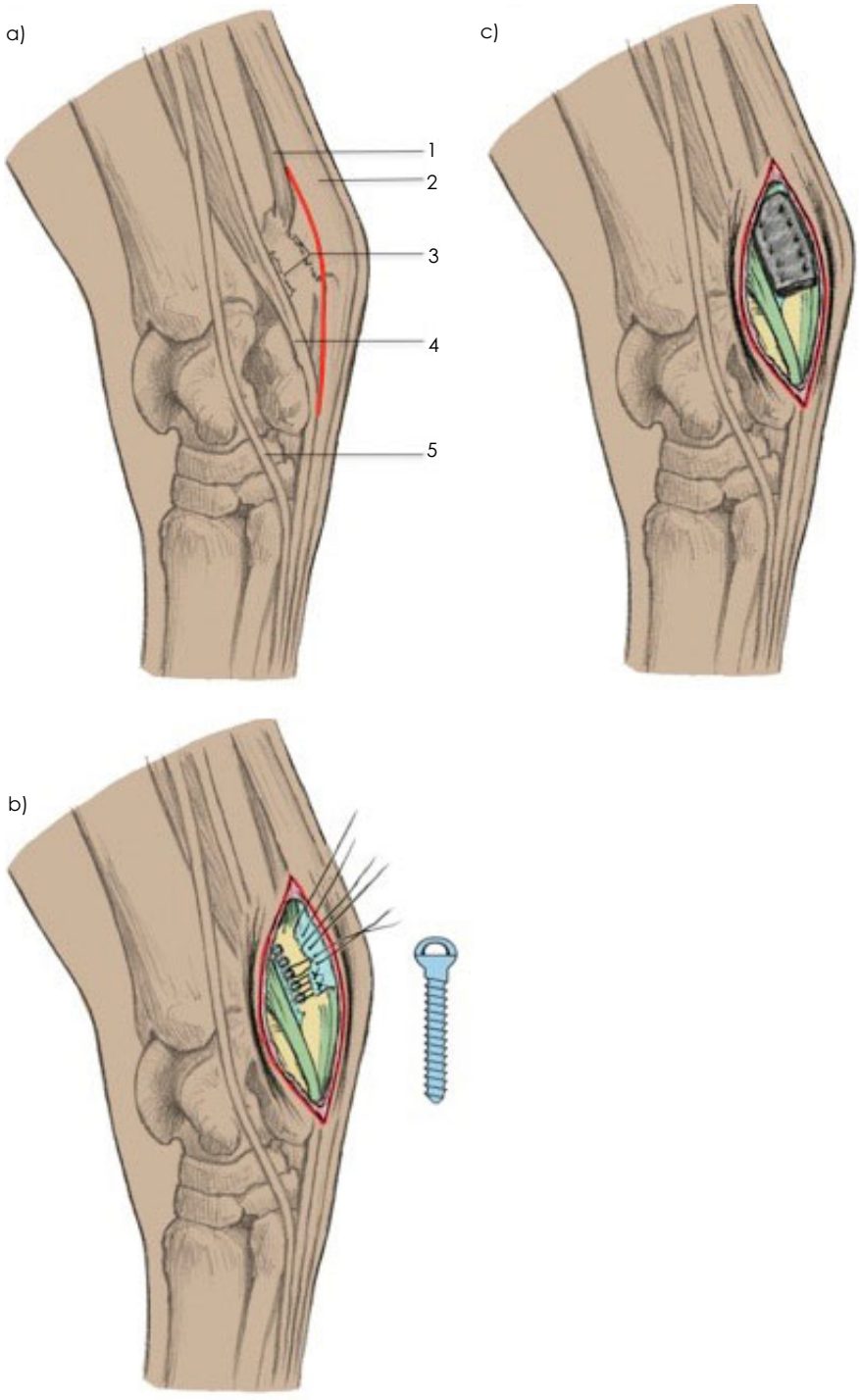
Data analysis

Continuous variables were reported as median (range). Categorical variables were reported as absolute values (percentages) for conservatively and surgically treated horses separately. In both treatment groups (surgical, conservative), the foals were described separately.

Results

Overall 16 mature horses and 2 foals were included in the study. There were 8 mares (44.4%), 8 geldings (44.4%) and 2 intact males (11.1%). All mature horses had either uni- or bilateral lateral luxations of the SDFT. Both foals presented

LOW RESOLUTION COLOR FIG



3 ***Fig 1: a) Schematic drawing of the medial aspect of a right tarsus in a horse suffering from a lateral luxation of the superficial digital flexor tendon (SDFT). The red line represents the skin incision made for the surgical approach. 1 = Gastrocnemius muscle, 2 = SDFT and its fibrocartilagnous cap (FCC), 3 = edges of the torn medial retinaculum, 4 = deep digital flexor tendon, 5 = tendon of the medial digital flexor muscle. b) The surgical incision including the skin (red), the subcutaneous tissue and the tarsal fascia (pink) is shown retracted. Portions of the gastrocnemius muscle (green, situated plantaroproximal) and deep digital flexor tendon (green, situated distodorsal) are visible as well as the medial aspect of the calcaneal tuber (yellow). Five suture screws are shown placed plantaromedially into the calcaneal tuber at the level of the insertion of the torn medial retinaculum (light blue). A schematic drawing of an enlarged 4.0 mm diameter self-taping suture screw with cancellous threads and an eye-head is shown on the right hand side. Large-diameter simple interrupted sutures are shown passed through the abaxial aspect of the FCC of the SDFT (the 2 most proximal sutures) and through the FCC of the SDFT and the eyelet of the suture screw (the middle suture). The 2 distal sutures have been tied to reattach the FCC of the SDFT to the calcaneal tuber via the suture screws. c) A synthetic mesh (grey) is shown fixed over the sutures and the suture screws using additional nonabsorbable suture material to reinforce the repair.***

with unilateral medial luxations of the SDFT. In 13 horses (72.2%) the right hind limb, in 3 horses (16.7%) the left hind limb and in 2 horses (11.1%) both hind limbs were affected.

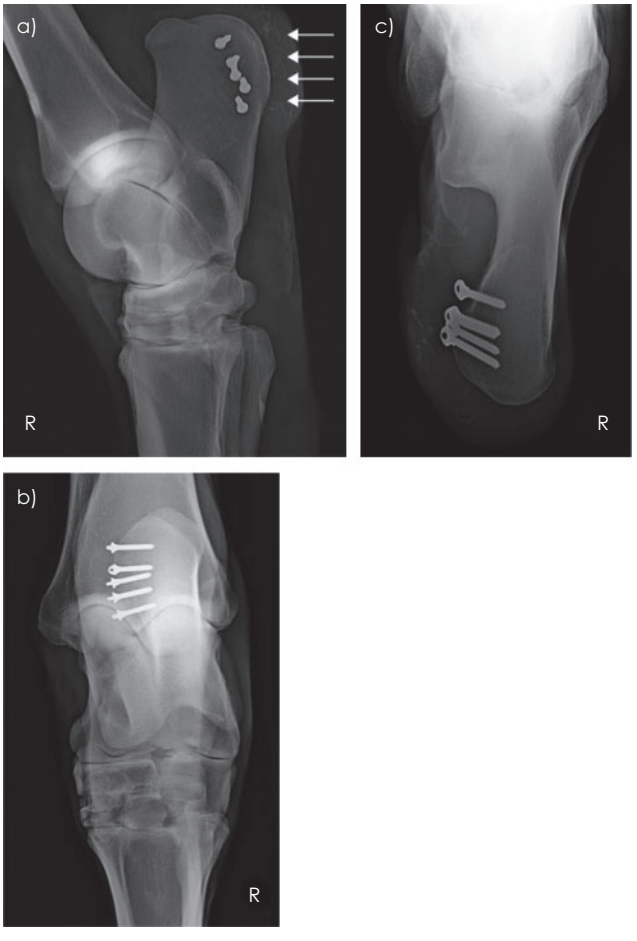
Seven mature horses and one foal were treated conservatively (44.4%) and 8 mature horses and one foal surgically (50%). One mature horse diagnosed with a bilateral luxation of the SDFT was subjected to euthanasia at presentation per owner's request and was excluded from the study.

Diagnostic imaging

The radiographic and ultrasonographic imaging findings are summarised in Supplementary Items 2 and 3. **Fig** 2 shows radiographs of Horse 13 obtained at the long-term follow-up examination.

Conservative treatment

Mature horses were age 12.5 years (6–19 years) and weighed 500 kg (400–600 kg). The foal was age 18 days old and weighed 65 kg. The duration from injury to admission was 90 days (1–180 days) for the mature horses and 7 days for the foal. At presentation 4 mature horses were grade 4 lame, 2 were grade 3 lame, 2 were grade 2 lame and the foal was grade 2 lame. The mature horses were stall rested for 3.2 months (5 days–6.4 months) with a full limb bandage (4/7) for 15 days (3–28 days). The foal was confined to a stall with a small paddock for 42 days without bandage. The mature horses received phenylbutazone (2.2 mg/kg bwt *per os*, q. 12 h; Equipalazone)[4] for 13 days (5–21 days). The foal did not receive any medication. The mature horses were hospitalised for 6 days (0–13 days). The foal was not hospitalised. The previous use, the complications during hospitalisation and the survival to hospital discharge of the conservatively treated horses are shown in Table 1.



4 ***Fig 2: Lateromedial a), dorsoplantar b) and skyline c) radiographic views of the right tarsus of Horse 13 at 9 years post-operatively. There is no evidence of new bone formation or signs of implant failure at the 5 suture screws. A moderate degree of soft tissue swelling and an ill-defined curvilinear mineralisation within the subcutaneous tissues at the site of the mesh and nonabsorbable suture material (white arrows) can be identified. There is a moderate degree of osteoarthritis visible in the distal and proximal tarsal joints.***

Surgical treatment

Mature horses were age 11 years (6–16 years) and weighed 527 kg (460–595 kg). The foal was age 58 days and weighed 112 kg. The duration from injury to admission was 90 days (1–180 days) for the mature horses and 3 days for the foal. At hospital admission 3 mature horses were grade 4 lame, 4 were grade 3 lame, one was grade 2 lame and the foal was grade 4 lame. Post–operatively, 3 mature horses were maintained in a sling for 26 days (10–42 days) with a full-limb bandage (Horses 10, 11 and 16) and 5 mature horses were stall rested with a full-limb cast for 16 days (5–28 days) followed by a bandage for 28 days (21–35 days; Horses 9, 12, 13, 14 and 15). The foal was stall rested with a full-limb cast for 28 days followed by a bandage for 28 days. The mature horses received 19 days (7–31 days) of phenylbutazone (2.2 mg/kg bwt *per os*, q. 12 h; Equipalazone)[4] and 17 days (3–31 days) of antimicrobials. All horses received Na-penicillin (30,000 iu/kg bwt i.v., q. 6 h.; Penicillin Natrium Streuli)[5] , and Gentamicin (6.6 mg/kg bwt, i.v., q. 24 h; Vetagent)[4]. In Horses 12 und 14 the antimicrobial treatment was changed to Marbofloxacin (2 mg/kg bwt, i.v., q. 12 h; Marbocyl 10%)[6] because of signs of infection at the implant site (reduced weightbearing, local cellulitis, intertendinous bursa effusion, systemic leucocytosis and increased body temperature). The foal received 7 days of firocoxib (0.1 mg/kg bwt, *per os* q. 24 h; Equioxx)[7] and 7 days of cefquinom (1 mg/kg bwt, i.m., q. 12 h; Cobactan)[4]. The mature horses were hospitalised for 46 days (17–75 days) and the foal for 3 days. The previous use, the implants used for the surgical repair, the recovery from general anaesthesia, the post-operative complications and the survival to hospital discharge of the surgically treated horses are shown in Table 2.

Long-term outcome

For the conservatively treated horses, long-term follow-up was obtained after 3.1 years (8.3 months–5.5 years) by orthop aedic examination (n = 4) and telephone questionnaire (n = 3). For the surgically treated horses, long-term follow-up was obtained at 9.3 years (2.4–16.1 years) post-operatively by orthopaedic examination (n = 2) and telephone questionnaire (n = 3).

Details on long-term survival, soundness and return to intended use as well as cosmetic outcome and the SDFT position and stability are shown in **Table** 1 and **Fig** 3**a** for the conservatively treated horses and **Table** 2 and **Fig** 3**b** for the surgically treated horses.

TABLE 1: An overview of the conservatively treated horses, and their short- and long-term outcomes

Horse	Background	Previous use	Complications during hospitalisation	Survival to hospital discharge	Duration of stall rest	Long-term survival	Return to intended use	Long-term cosmetic outcome	Long-term SDFT position and stability
1	MC, WB, 12 years	Showjumping	None	Yes	No information	Lost to Follow-up			
2	MC, WB, 16 years	Eventing	None	Yes	No information	Yes	No, lower level showjumping	Mild thickening calcaneal region	Lateral, unstable
3	F, WB, 16 years	Breeding	None	Yes	3 months	Yes	Yes	No information	Lateral, unstable
4	MC, TB, 6 years	Racing	None	Yes	6 weeks	Yes	Yes	Mild thickening calcaneal region	Lateral, unstable
5	F, Pony, 17 years	Pleasure riding	None	Yes	5 days	Yes	Yes	Moderate thickening calcaneal region	Lateral, unstable
6	F, WB, 19 years	Pleasure riding	None	Yes	6 weeks	Yes	No, pasture sound	Severe thickening calcaneal region	Lateral, unstable
7	MC, WB, 15 years	Pleasure riding	None	Yes	6.4 months	Yes	Yes	Moderate thickening calcaneal region	Lateral, unstable
8	M, WB, 18 days	Intended for showjumping	None	Yes	10 days	Yes	Yes, showjumping	No thickening	Plantaro-medial, unstable

SDFT, superficial digital flexor tendon; F, female, MC, male castrated, M, male, WB, Warmblood, TB, Thoroughbred.

Post-mortem *examination*

Horses 12 and 14 were subjected to euthanasia due to implant infection alone or in combination with laminitis. At post-mortem examination in Horse 12, loose suture screws due to osteomyelitis following implant infection were identified. In Horse 14, fibrin was visible around the implants macroscopically and the tissue around the sutures showed evidence of a neutrophilic infiltration and degeneration histologically. No necropsy was performed on Horse 15.

Horses 9 and 16 were subjected to euthanasia for reasons unrelated to the surgery. In Horse 9 (subjected to euthanasia due to old age 16 years postoperatively), the mesh and sutures were intact and embedded in scar tissue. The histological examination revealed no signs of inflammation in the surrounding tissue. In Horse 16 (subjected to euthanasia due to colon torsion 4 months post-operatively), the mesh, the sutures and the suture screws were intact and the repair stable.

Discussion

This study reports the outcome of horses either treated conservatively or surgically for luxations of the SDFT from the calcaneal tuber. Following conservative treatment, 71.4% (5/7) of the horses returned to their intended use long term, despite suffering from a mild mechanical lameness and a mild outward rotation of the limb due to the nonphysiological position of the SDFT. Surgical treatment leaded to long-term soundness and return to intended use in 80% (4/5) of the horses available for follow up. In 80% (4/5) of the horses, the repair was intact and the SDFT was stably fixated over to the plantar aspect of the calcaneal tuber. However, fatal complications (laminitis and implant infection) occurred in the post-operative period and only 66.7% (6/9) of the horses survived to hospital discharge after surgical treatment. In contrast, the survival to hospital discharge after conservative treatment was of 100% (8/8). Considering the high morbidity and mortality following surgical treatment, conservative treatment should be recommended to owners, with the goal to preserve the horse's life independent of any mechanical gait impairment. Surgical treatment results in the best possible biomechanical result, but is associated with fatal complications in the post-operative period.

Awareness and aggressive pre-emptive management of support limb laminitis is considered a priority and may have a positive effect on the survival rate following surgical repair. Several factors resulting in reduced weightbearing were present in Horses 14 and 15 which were subjected to euthanasia due to support limb laminitis. Post-operative pain due to increased strain on the surgically fixated SDFT may have resulted in poorer weightbearing in the surgically treated horses in comparison to the conservatively treated horses. Furthermore, pain originating from a surgical site infection, as occurred in Horse 14, may have worsened weight bearing. Additionally, both horses had the operated limb stabilised with a full-limb cast. An association between full-limb casts and the occurrence of support limb laminitis has been reported (Virgin *et al.* 2011). Horses requiring casts for longer periods of time and those requiring full-limb casts or transfixation casts as opposed to half-limb casts were at an increased risk for developing support limb laminitis (Virgin *et al.* 2011). In the authors' experience many horses do not

TABLE 2: An overview of the surgically treated horses, their complications and their short- and long-term outcomes

Horse	Background	Previous use	Implants	Recovery	Complications during hospitalisation	Survival to hospital discharge	Long-term survival	Return to intended use	Long-term cosmetic outcome	Long-term SDFT position and stability
9	F, WB, 16 years	Pleasure riding	Mersilene mesh Ethibond metric 6	Rope assisted/Full limb cast	Seroma formation	Yes	Yes	Yes	Thickening over implants	Plantar, stable
10	F, Pony, 15 years	Polo	Mersilene mesh Ethibond metric 6	Pool/Hydrophobic bandage	Implant failure 73 days PO SDFT re-luxation	Yes	Yes	Yes	Thickening over calcaneal tuber	Lateral, stable
11	M, TB, 6 years	Racing	5 suture screws Mersilene mesh Ethibond metric 6	Pool/Hydrophobic bandage	None	Yes	Yes	No, pleasure riding	No information	Plantar, stable
12	MC, WB, 12 years	Show jumping	4 suture screws Mersilene earsmesh Novafil metric 2	Rope assisted/Full limb cast	Implant infection	Euthanasia 21 days PO	No			
13	MC, TB, 16 years	Pleasure riding	5 suture screws Mersilene mesh Fiberwire metric 5	Rope assisted/Full limb cast	Cast sores	Yes	Yes	Yes	Thickening over implants	Plantar, stable
14	F, Arabian, 12 years	Pleasure riding	4 suture screws Fiberwire metric 5/2	Rope assisted/Full limb cast	Implant infection, support limb laminitis,	Euthanasia 42 days PO				
15	F, WB, 7 years	Eventing	5 suture screws Fiberwire metric 5	Rope assisted/Full limb cast	Support limb laminitis	Euthanasia 42 days PO				
16	MC, WB, 15 years	Jumping	5 suture screws Mersilene mesh Fiberwire metric 5/2	Pool/Hydrophobic bandage	Cellulitis at the surgical site	Yes	No (Colon torsion 4 months PO)			
17	F, TB, 58 days	Intended for racing	4 suture screws Fiberwire metric 5	Rope assisted/Full limb cast	None	Yes	Yes	Yes, in racing training	Thickening over calcaneal tuber	Plantar, stable

SDFT, superficial digital flexor tendon; F, female, MC, male castrated, M, male, WB, Warmblood, TB, Thoroughbred, PO, post-operative.

COLOR

Fig 3: a) Photographs showing the left hock from plantar (left) and lateral (right) of a conservatively treated horse (Horse 6). The superficial digital flexor tendon is shown situated laterally to the calcaneal tuber. b) Photographs showing the right hock from plantar (left) and lateral (right) of a surgically treated horse (Horse 13). The fibrocartilaginous cap of the superficial digital flexor tendon is stably fixed over the calcalneal tuber. Notice the moderate thickening medially over the implants (white arrows).

accept full-limb casts well and overload the contralateral limb. Premature cast removal can be necessary in case of nonacceptance because of the risk of laminitis (Phillips 2000). To prevent this complication, we recommend using slings (or other measures) to prevent the horses from lying down in the early post-operative period rather than keeping them in full-limb casts for long periods. Additionally, careful monitoring and aggressive post-operative multimodal pain management can significantly improve patient welfare and outcome (Love 2012). The combined use of nonsteroidal anti-inflammatory drugs, epidural analgesia and continuous intravenous infusions of ketamine, lidocaine or butorphanol (Goodrich 2009; Love 2012) should be considered to improve weightbearing.

The rate of post-operative orthopaedic infections following long bone fracture repair and arthrodesis was reported to be 28% (Ahern *et al.* 2010). This is comparable to our study where the implant infection rate was 22.2% (2/9). The implant infections were managed with systemic and local administration of antimicrobials (intrasynovial injections of the intertendinous calcaneal bursa). In Horse 14 the infection was managed successfully. The horse was, however, subjected to euthanasia due to support limb laminitis. In Horse 12 the infection did not resolve. Implant removal was discussed with the owner, who refused to allow a second surgery. The horse was subjected to euthanasia 21 days post-operatively with poor weightbearing, radiographical lysis surrounding the screws and evidence of an infected

intertendinous calcaneal bursa. The implant infections in these 2 horses made a prolonged administration of antimicrobials necessary (21 days in Horse 12, 31 days in Horse 14). These 2 values increased the median duration of antimicrobial use (17 days) in our study.

In the first 2 horses operated on (Horses 9 and 10), only a synthetic mesh and sutures were used to replace the torn retinaculum. In these horses, only a minimal amount of retinaculum was available at the insertion site into the calcaneal tuber for suture purchase and in addition, the remaining fibres were very friable. Therefore, it was challenging to tie the sutures without pulling them through the retinaculum. Following SDFT reluxation in horse 10, the operation technique was modified (as shown in **Fig** 1). In the authors experience, the eyelets of the screws represent a much stronger anchor for the sutures than the remaining retinaculum fibres allowing a solid fixation of the FCC to the calcaneal tuber. A synthetic mesh was applied over the sutures to allow a better distribution of the suture strain and prevent suture pull out at the abaxial aspect of the FCC. After using the technique (as shown in **Fig** 1) no further implant failure has occurred and the authors recommend using this technique if a surgical repair is attempted. Experience from using these suture screws in other surgical repairs (i.e. prosthetic capsule treatment for coxofemoral luxation [Kuemmerle and Fürst 2011;]) have shown that the fairly sharp eyelet of these screws represents a potential weak point of the repair. The use of different anchor screws (i.e. HEALIX TI dual threaded suture anchors[8] with integrated suture material) may be a further possibility when implant failure does occur.

Failure of the surgical repair occurred in Horse 10 and therefore a persistent mechanical lameness could have been expected thereafter similar to horses undergoing conservative treatment. However, in this horse, the SDFT was stable on the lateral aspect of the calcaneal tuber and no mechanical lameness was present at the long-term follow-up examination. Wright and Minshall (2012) described a buttonhole effect with the calcaneus protruding into the defect of the torn FCC preventing a complete subluxation and resulting in lameness. The bursoscopic removal of the disrupted and inhibitory tissue created a stable subluxation of the SDFT (Wright and Minshall 2012). The surgical debridement of the torn retinaculum at the time of surgery in Horse 10 may have prevented the above described buttonhole effect and resulted in the stable lateral luxation of the SDFT seen in this case.

The described minimally invasive bursoscopic approach is associated with a lower morbidity than our open approach (Wright and Minshall 2012); however, it is important to keep the aim of the surgical treatment in mind. Wright and Minshall (2012) aimed to obtain a stable luxation of the SDFT and our goal was to restore the correct anatomic position of the SDFT over the calcaneal tuber. For this, an open approach was necessary in order to fixate the SDFT to the calcaneal tuber. Furthermore, the inclusion criteria regarding the clinical presentation of the horses were different between the 2 studies. In our study only horses with unstable luxations of the SDFT were included. In contrast to that, Wright and Minshall (2012) only had a few horses with unstable luxations (7/19) and mainly described horses with stable luxations (12/19). Following bursoscopy 86.7% (6/7) of the horses with unstable luxations went back to work but only 57.1% (4/7) went back to their previous level of use (Wright and Minshall 2012). Following fixation of the SDFT to the calcaneal tuber with our surgical technique 80% (4/5) of the horses surviving long-term went back to their intended use.

In this study, lateral luxations of the SDFT were more common than medial ones. This concurs with the literature (Scott *et al.* 1982; Scott 1983; Meagher and Aldrete 1989; Reiners *et al.* 2000; Auer 2012; Wright and Minshall 2012). In the current study, only foals suffered from medial SDFT luxations. This was an unexpected and previously unreported finding. In mature horses, the medial calcaneal retinaculum is thinner than the lateral (Barker and Wright 2014), which could explain why it is more prone to rupture. In foals, the exact anatomy of the retinaculae has not been described and cases of SDFT luxation are not yet reported. Our finding of 2 foals is inadequate to postulate that medial luxations may occur more frequently in immature patients. Further evaluation of foals with SDFT luxations will be necessary to support this conclusion.

This study has limitations common to all retrospective studies. The main limitation is that treatment type (conservative or surgical) was not randomly assigned to the admitted horses. Treatment was chosen by the owner and was biased by many factors including the value of the horse, the owner's expectations and the financial situation. For this reason, the different outcome parameters of the conservatively and surgically treated horses cannot be statistically compared. The authors acknowledge that the intended use of 3 of the surgically treated mature horses was pleasure riding and the foal who was intended for racing was only in training at the time of follow-up. Thus, the prognosis for the return to intended use of the published surgically repaired horses should not be extrapolated to horses performing at higher athletic level.

Conclusion

The results of this study suggest that conservative treatment of luxations of the SDFT from the calcaneal tuber is a safe and viable option, especially with respect to long-term survival. Despite persistence of a mechanical lameness due to the unstable SDFT, the use of the horse as previously intended will be possible in most cases. Surgical fixation of SDFT luxation can result in sound horses returning to their intended use. However, dramatic complications related to the surgery can result in euthanasia. These complications require early recognition and aggressive prevention measures to improve the hospital survival rate with surgical repair. Re-luxation following implant failure was prevented using a combination of suture screws and a synthetic mesh.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable: retrospective study.

Source of funding

Xxxx.

Acknowledgements

The authors thank Matthieu Cousty for adding Horse 17 to this study and Matthias Haab for the schematic illustrations.

Authorship

All authors have made substantial contributions to the study design, the study execution, the data analysis and interpretation as well as the manuscript preparation. All authors have given their final approval of the manuscript.

Manufacturers' addresses

[1]Veterinary Instrumentation, Sheffield, South Yorkshire, UK.
[2]Ruedi Keller, Embrach, Switzerland.
[3]Benzler, Dental, AG, Zürich, Switzerland.
[4]MSD Animal Health GmbH, Luzern, Switzerland.
[5]Streuli Pharma AG, Uznach, Switzerland.
[6]Vetoquinol AG, Bern, Switzerland.
[7]Merial, Lyon, France.
[8]DePuy Synthes, Zuchwil, Switzerland.

References

AAEP Horse Show Committee (1999) *Guide to Veterinary Services for Horse Shows*, 7th edn., American Association of Equine Practitioners, Lexington.

Ahern, B.J., Richardson, D.W., Boston, R.C. and Schaer, T.P. (2010) Orthopedic infections in equine long bone fractures and arthrodeses treated by internal fixation: 192 cases (1990-2006). *Vet. Surg.* **39**, 588-593.

Auer, J.A. (2012) Tarsus. In: *Equine Surgery*, 4th edn., Eds: J.A. Auer and J.A. Stick, Elsevier Saunders, St Louis. pp 1402.

Barker, W.H. and Wright, I.M. (2014) Morphologic and morphometric features of the calcaneal insertions of the superficial digital flexor tendon in the horse. *Vet. Comp. Orthop. Traumatol.* **27**, 366-371.

Baxter, G.M. and Morrison, S. (2008) Complications of unilateral weight bearing. *Vet. Clin. North. Am.: Equine Pract.* **24**, 621-642.

Dyson, S. (2010) Other soft tissue injuries. In: *Diagnosis and Management of Lameness in the Horse*, 2nd edn., Eds: M. Ross and S. Dyson, Elsevier, St Louis. pp 411-412.

Fürst, A., Keller, R. and Von Salis, B. (2006) Entwicklung eines verbesserten Hängegeschirrs für Pferde: Das Tier - Bergungs- und Transportnetz (TBTN). *Pferdeheilkunde* **22**, 767-772.

Goodrich, L.R. (2009) Strategies for reducing the complication of orthopedic pain perioperatively. *Vet. Clin. Equine* **24**, 611-620.

Kuemmerle, J.M. and Fürst, A.E. (2011) Treatment of a coxofemoral luxation in a pony using a prosthetic capsule technique. *Vet. Surg.* **40**, 631-635.

Love, E.J. (2012) Equine pain management. In: *Equine Surgery*, 4th edn., Eds: J.A. Auer and J.A. Stick, Elsevier Saunders, St Louis. pp 263-269.

Meagher, D.M. and Aldrete, A.V. (1989) Lateral luxation of the superficial digital flexor tendon from the calcaneal tuber in two horses. *J. Am. Vet. Med. Ass.* **195**, 495-498.

Phillips, T. (2000) Dislocation of the superficial digital flexor tendon from the tuber calcanei. *Proc. Br. Equine Ass. Congress.* **39**, 82.

Picek, S., Kalchofner, K.S., Ringer, S.K., Kummer, M., Fürst, A. and Bettschart-Wolfensberger, R. (2010) Anaesthetic management for hydropool recovery in 50 horses. *Pferdeheilkunde* **26**, 515-522.

Reiners, S., Jann, H. and Gillis, E. (2000) Repair of medial luxation of the supfercicial digital flexor tendon in the pelvic limb of a filly. *Equine Pract.* **22**, 18-21.

Scott, E.A. (1983) Surgical repair of a dislocated superficial digital flexor tendon and fractured fibular tarsal bone in a horse. *J. Am. Vet. Med. Ass.* **183**, 332-333.

Scott, E.A., Breuhaus, B. and Gertsen, K.E. (1982) Surgical repair of dislocated superficial digital flexor tendon in a horse. *J. Am. Vet. Med. Ass.* **181**, 171-172.

Virgin, J.E., Goodrich, L.R., Baxter, G.M. and Rao, S. (2011) Incidence of support limb laminitis in horses treated with half limb, full limb or transfixation pin casts: a retrospective study of 113 horses (2000-2009). *Equine Vet. J.* **40**, *Suppl.* **43**, 7-11.

Wright, I.M. and Minshall, G.J. (2012) Injuries of the calcaneal insertions of the superficial digital flexor tendon in 19 horses. *Equine Vet. J.* **44**, 136-142.

Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Supplementary Item 1: Video.

Supplementary Item 2: Radiographic findings at presentation, short-term recheck (only performed in surgically treated horses) and long-term recheck of the conservatively and surgically treated horses.

Supplementary Item 3: Ultrasonographic findings at presentation, at the short-term recheck (only performed in surgically treated horses) and at the long-term recheck of the conservatively and surgically treated horses.

MARKED PROOF

Please correct and return this set

Please use the proof correction marks shown below for all alterations and corrections. If you wish to return your proof by fax you should ensure that all amendments are written clearly in dark ink and are made well within the page margins.

Instruction to printer	*Textual mark*	*Marginal mark*
Leave unchanged	··· under matter to remain	New matter followed by ⌐ or ⌐(x2)
Insert in text the matter indicated in the margin	⌐	
Delete	/ through single character, rule or underline or ⊢⊣ through all characters to be deleted	⌐/ or ⌐/(x2)
Substitute character or substitute part of one or more word(s)	/ through letter or ⊢⊣ through characters	new character / or new characters /
Change to italics	— under matter to be changed	⌐
Change to capitals	≡ under matter to be changed	≡
Change to small capitals	= under matter to be changed	=
Change to bold type	~ under matter to be changed	~
Change to bold italic	≈ under matter to be changed	≈
Change to lower case	Encircle matter to be changed	≡/
Change italic to upright type	(As above)	⌐+
Change bold to non-bold type	(As above)	~+
Insert 'superior' character	/ through character or ⌐ where required	Y or Y under character e.g. Y^{3} or Y^{3}
Insert 'inferior' character	(As above)	⌐ over character e.g. Y_{2}
Insert full stop	(As above)	⊙
Insert comma	(As above)	,
Insert single quotation marks	(As above)	Y or Y and/or Y or Y
Insert double quotation marks	(As above)	Y or Y and/or Y or Y
Insert hyphen	(As above)	⊢
Start new paragraph	⌐	⌐
No new paragraph	⌒	⌒
Transpose	⊔	⊔
Close up	linking ⌒ characters	⌒
Insert or substitute space between characters or words	/ through character or ⌐ where required	Y
Reduce space between characters or words	| between characters or words affected	⊤